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Research Article

THE ROLE OF KARST FORMATIONS IN GROUNDWATER RESOURCES DEVELOPMENT

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ABSTRACT
Karst geomorphology is result of karstification situation that it separates the karst areas from none of karst areas. This study investigated karst geomorphology and hydrogeology and springs quality for groundwater resource development in Hormozgan province in south of Iran. PH, TDS, SAR, EC, cations and anions were used for springs hydrochemistry analysis using Piper, Wilcox and Scholler's diagrams and the karst formations were used for amplitude of groundwater resources. Result of analysis show that Tidar and Bekhon springs have good quality in study area. On the other hand, Sarvak and Pabde formations have good permeability in the study area. Overall, by considering the results, Pabde and Sarvak formations play role of the important in groundwater resource development in the study area.

Key Words: *Karst, Hydrogeology, Wilcox, Schooler and Piper Diagrams, Sirmand, Hormozgan, Iran*

INTRODUCTION
The word karst can be traced back to pre- Indoeuropean origins (Gams 1973a, 1991a, 2003; Kranjc, 2001b). It stems from Karra/gara meaning stone, and its derivatives are found in many languages of Europe and the Middle East. Ford and Williams (2007) define the karst as comprising terrain with distinctive hydrology and landforms that arise from a combination of high rock solubility and well developed secondary (fracture) porosity. Such areas are characterized by sinking streams, caves, enclosed depressions, fluted rock outcrops, and large springs.
Karst is characterized by the predominance of rock dissolution over mechanical erosion, and is typical of present temperate (cold and warm) and tropical environments (Ford and Williams, 2007). Karst water resources have been important for millennia people in the world, such as karst springs are as significant important in resource of fresh water in the world. Survival of mankind was possible thanks to its ability to adapt to an ever-changing environment and its capability to learn and communicate the new findings. From the earliest times, geomorphic features and processes were an essential part of social survival (Crozier *et al.*, 2011). Unfortunately, the number of karst areas affected by water pollution, landscape degradation and other impacts is growing very rapidly. Additionally, the damage caused by hazardous karst processes, especially subsidence sinkholes (Beck, 2003; Waltham *et al.*, 2005; Gutiérrez *et al.*, 2008a), will most likely keep on increasing. Exposed human elements augment and anthropogenic changes in the karst systems frequently result in hazard enhancement. Karst geomorphologists and hydrologists can play a decisive role in preventing natural disasters in karst areas, particularly those induced by human activities (Milanovic, 2000; Cooper and Gutiérrez, 2011).
Iran is a vast country that has a wide variety of soluble rocks, especially carbonates. Karst groundwater is a major water resource in many regions of some countries such as China, Turkey, Iran, the United States, etc. Karstic-carbonate formations cover about 11% of the land area in Iran (185,000 km^2) and 55% of the Zagros region (Raeisi, 2004). These studies are essential for groundwater development, so management of the karst resources is important significantly, because the number of population increased daily and it can be lead to be water leakage. Thus, it is necessary that it should be as a comprehensive management in karst water resource control.

MATERIAL AND METHODS

Study Area

The Sirmand (Haji-Abad) watershed is located in $56° 2´ 16"E$ and $27° 54´ 55"N$ in Hormozgan province with 172.7 km^2in about 150 km north of Bandar Abbas city, the capital city of Hormozgan province (Fig1). Mean elevation is about 1950.5 (varies from 1008 to 2893). Rainfall average is 302.2 mm and most of rainfall is in Winter (February and Mars).Percentage of relative humidity is 35.2%. It is high in January and February and low in May and August. Temperature mean is 23.4 ℃. It varies from 2.6 to 45.6 ℃ and climate is arid-semiarid. Geological formations are part of Zagros Folded and High zone. Based on the FAO international classification method (Dewan and Famouri, 1964) soils in the study area have been classified a major group. It is (Biburdi, 1981) Lithosol. Main vegetation types are Convolvulus spinosus, Cymbopogonoliveri, Astragalus fascicolifolius (shrub).There is not Hydrometric station so surface flows value are calculated from adjacent stations. Annual run off height value, discharge, and run off coefficient have been calculated 97.4 mm, 0.55 $m^3$and 32.7% , respectively. Permeability value are 25, 18.07, 3.84 and 4 % for Pabde, Sarvak, Bakhtiyari and Jahrom- Asmari formations in the study area, respectively.

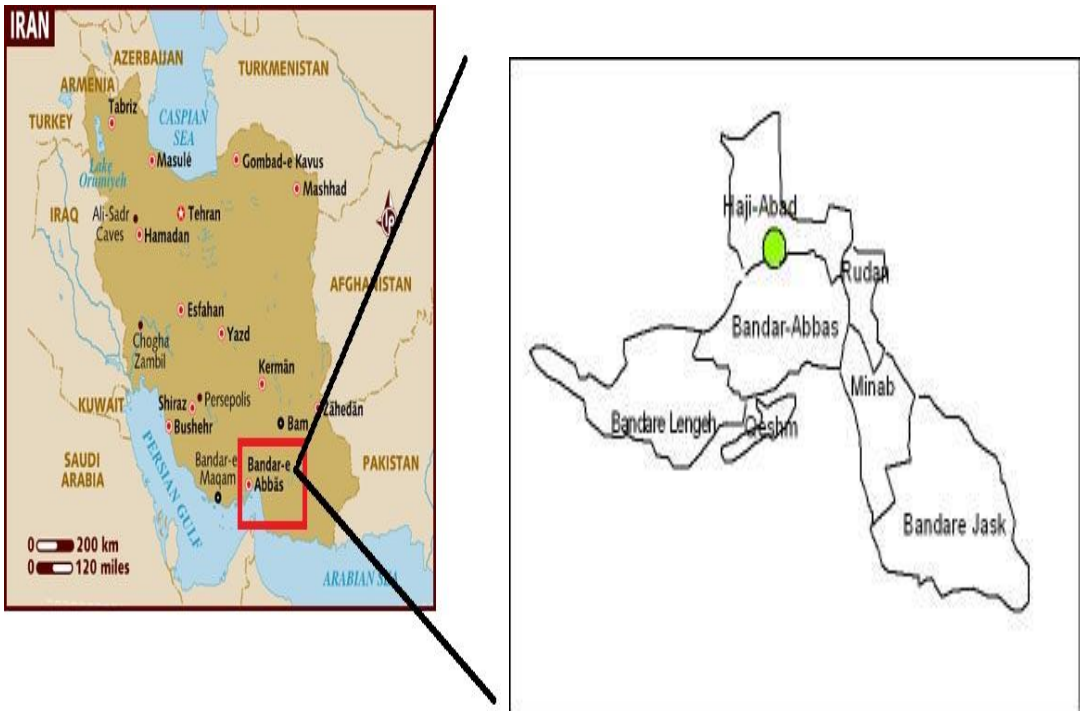

Figure 1: The study area in Iran, Hormozgan Province, Sirmand(Haji-Abad) Watershed

Data Sources

Data such as rainfall and temperature data (Bureau of Meteorology of Iran, 2011) and spring water analysis, PH and TH (Total of Hardness) (Hormozgan Water Corporation Organization, 2011) were obtained for 4 years (2008-2011), and used for the selected springs analysis calculation.

Geology of Study Area

The geology and especially the tectonic style of Iran is highly influenced by the development and history of the Tethyan region. The tectonic events, which occurred around the Iranian Plate margins, are related to rifting processes of Gondwana and subsequent collision with the Arabian plate from the WSW. These important processes affected the Iranian Plate and the adjacent plates, such as the African, Indian,

Arabian, and Eurasian Plates, during Mesozoic to Tertiary times (Alsharhan *et al.,* 2002; Alavi, 2004). The Zagros Mountains are the result of complex deformation processes, which started in Late Cretaceous time. These deformations are due to the collision of the Arabian and Iranian Plates. The deformation rate increased during the Pliocene time due to increased convergence rate by the opening of the Red Sea (Sattarzadeh *et al.,* 2000). The study area has been located in Zagros zone includes the folded and thrust Zagros.

The Folded Zagros consists mainly of thick marine sediments of several thousand meters depth. The stratigraphic sequence comprises sediments of Mesozoic and Neogene ages, which have been deposited in a basin. These sediments were folded and uplifted mainly during the Upper Miocene / Lower Pliocene (Allen *et al.,* 2004) to the Pleistocene. As a result, the Zagros fold-belt has been formed.

The High Zagros (historically known as Zagros Crushed zone and Zagros Thrust zone (Stocklin, 1968) marks the plate boundary between the Arabian Plate to the west and the Iranian plates to the east.

Karst Geomorphology

Geomorphology defines the processes and conditions that influence landform development, and the physical, morphological, and structural characteristics of landforms. In fact, Karst geomorphology is result of karstification situation that it separates the karst areas from none of karst areas.

In karst terrains, surface and subsurface geomorphology and hydrology are largely governed by dissolution of carbonate and/or evaporite rocks. In the most classical (common) situation, surface waters, acidified by CO2 from the air and soil, slowly dissolve carbonate rocks while percolating downwards and flowing down-gradient in the phreatic (saturated)zone towards the discharge points, typically springs. Dissolution is greater close to the surface, in the so-called epikarst (Williams, 2008; Palmer, this issue), and tends to decrease rapidly downwards. This process causes that a difference karst morphology is created with carbonate dissolution. Such as Lapie, Doline (sinkhole), Karren, polje and cave.

Karren: it is another type of carbonate dissolution surface morphology that creates by the dissolution joints and surface flow on carbonate rocks.

Polje: A polje is a large flat plain in karst territory, often structurally controlled.

Aven: it is another type of carbonate dissolution surface morphology that creates vertically by solution holes in carbonate rocks.

Cave: Cave systems are formed when dissolution produces a series of caves. In fact, it is depend on fluctuating groundwater table.

Karst Hydrogeology

Karst groundwater displays many of the characteristics of underground water in rocks. Karst groundwater is one of the important resources for world population. One of these resources is springs. There are 4 springs in this study that their information are follow as:

Table 1: Springs location in the study area

X	Y	Spring
408248	3094858	Siyahak
410714	3097411	Sirmand
420226	3092945	Bekhon
420535	3093461	Tidar

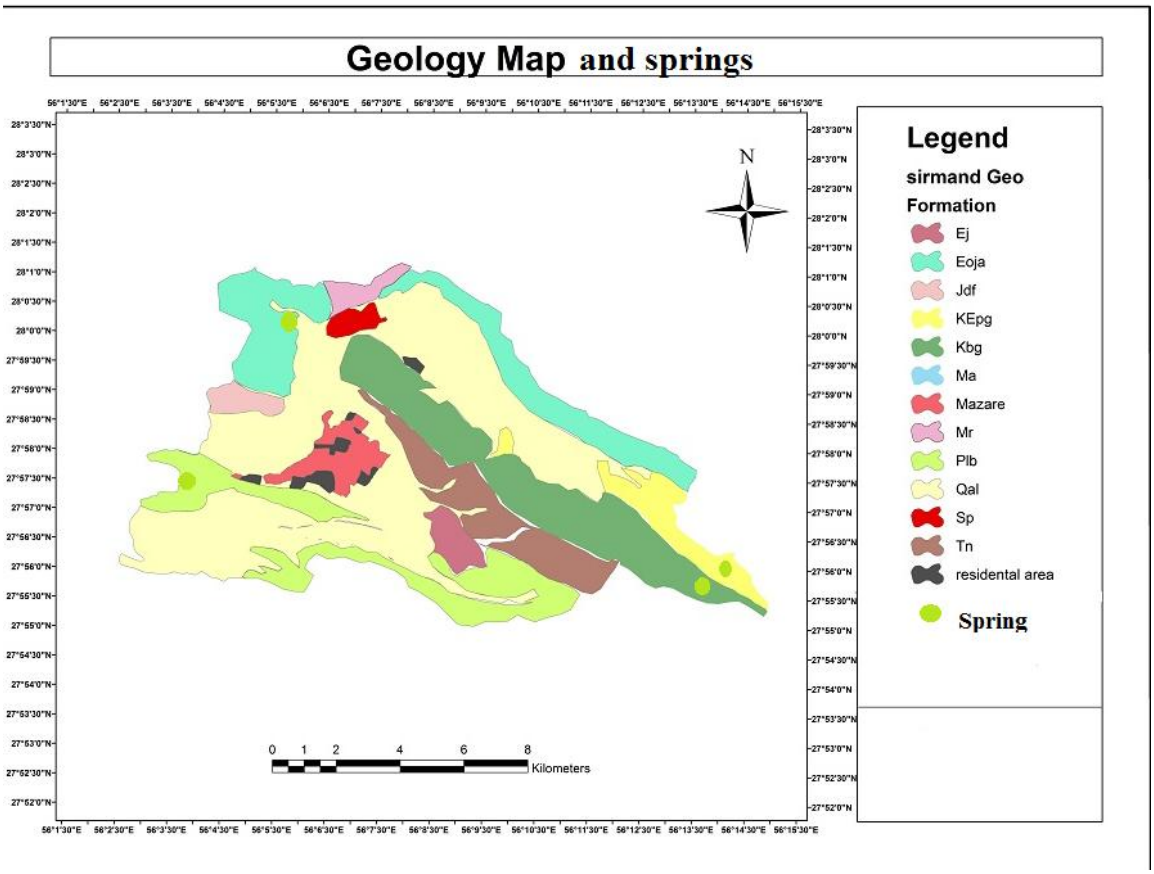

Figure 2: Geology map and available springs in the study area

Figure 2 shows that available lithology in this study area are includes of Limestone, Marl and Shale. The springs located on the Plb (Bakhtiyari Conglomerates), EO_{Ja} (Jahrom- Asmari), kE_{Pg} (Pabde) and K_{bg} (Sarvak) formations. Bakhtiyari, Jahrom- Asmari, Pabde and Sarvak formations situated in west (Siyahak springs), western north (Sirmand springs) and eastern south (Tidar and Bekhonsprings) of watershed, respectively.

Karst springs are locations where groundwater emerges from the limestone and flows across the surface forming a stream or contained pool. The flow of karst springs is generally dependent on the weather and climate. Some are more permanent than others, while others only flow following rainfall or snowmelt events. Springs that are connected to aquifers flow year-round and support rich aquatic biodiversity. Karst springs generally do not support good water quality, and thus are not safe for drinking without filtering the water first; however, the springs often provide fun recreational opportunities and can be a popular place for swimming and snorkeling. With regard to its important, karst hydrogeology has made great progress in the past decennia, but still needs to be investigated in more detail and by applying new approaches (Goldscheider and Ravbar, 2010; Palmer, 2010).

For identifying the springs water quality are needs to their analysis. There are numerous diagrams to water quality analyzing. In this paper, it has used Wilcox, Schollers and Piper diagrams for water quality analyzing.

Wilcox Diagram

Wilcox (1948) used percentage sodium and electrical conductance to evaluate the suitability of groundwater for irrigation. The electrical conductivity depends on the amount of salt water is ionized water. In fact, the electrical conductivity is as an index of the standard that describes the salt

concentration of available in the water. The sodium absorption ratio (SAR) of irrigation water, as an index to determine the risks of sodium used in the soil and water increasing the amount of the sodium ions in the soil and irrigation water, cause increase soil and water salinity; and problems in terms of plant growth and soil physical properties and hydraulic conductivity are created.

Table 2: Classification of water for agricultural purposes based on Sodium adsorption ratio and electrical conductivity, according to Wilcox diagram method

m.m/cm (E.C)	SAR		
	Classification		Classification
100-250	Excellent C_1	<10	Excellent S_1
250-750	Good C_2	10-18	Good S_2
750-2250	Middle C_3	18-26	Middle S_3
>2250	Inappropriate C_4	>26	Inappropriate S_4

Piper Diagram

A piper diagram is a graphical representation of the chemistry of a water sample. The cations and anions are shown on separate ternary plots. The apexes of the cation plot are Ca, Mg and Na+Kcations. The apexes of the anion plot are SO4, Cl and CO3+HCO3. The 2 ternary plots are then projected onto a diamond. The diamond is a transformation of the graphs of the anions and cations.

Scholler's Diagram

The evolution of hydrochemical parameters of groundwater can be understood by plotting the concentration of major cations and anions in the Schoeller's diagrams.

RESULT AND DISCUSSION

Karst landscapes are characterized by fluted and pitted rock surfaces, Polje, Karren, springs, sink holes, subsurface drainage systems, and caves. The unique features and three-dimensional nature of karst landscapes are the result of a complex interplay between geology, climate, topography, hydrology, and biological factors over long time scales. There are example of karst morphologies at all latitudes and elevations that covering the earth landforms.

Figure 3(a): Karren-Karst landformes in the study area

Figure 3(b): Jenab Ali Cave-Karst landformes in the study area

Figure 3(c): Polje-Karst landformes in the study area

Figure 3(d): Aven-Karst landformes in the study area

In figure 3, Karren, Polje and Aven are considers as surface karst and cave is considers as deep karst. According to figure 3, Karrens control the water flows and these are affect in hydrological cycle and ground waters aquifer recharge. In general, the karst landforms have an attractive natural landscape in the world.Karst landforms are one of important regions to tourisms in the Hormozgan province in south of Iran.Furthermore, recognition of karst landforms helping to recognizes groundwater resource and water budget. Therefore, it is important that it should be considered as an essential factor in groundwater resources development.

Wilcox Diagram

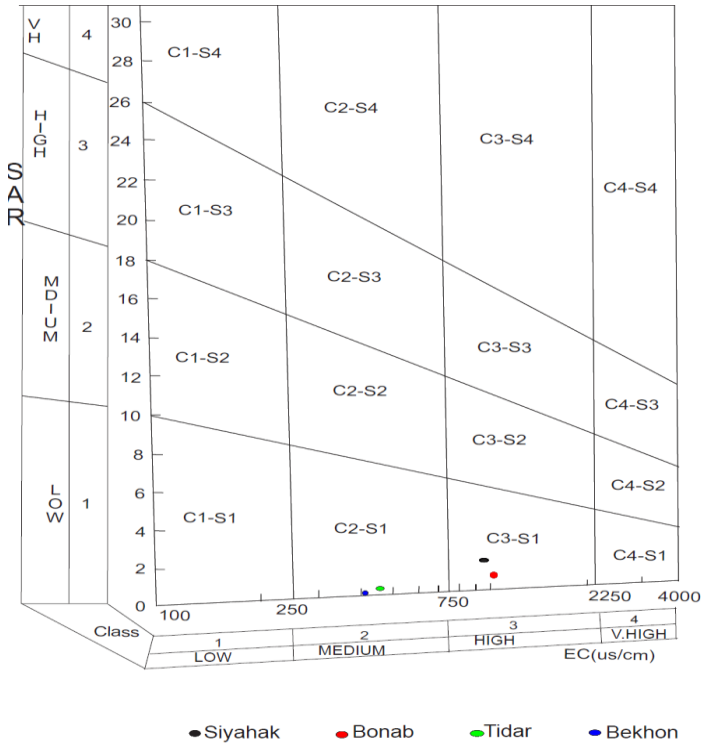

Figure 4: Springs water quality analyzing using of Wilcox diagram

In figure 4, Wilcox diagram shows relationship between EC (electrical conductivity) and SAR (sodium absorption ratio). In this diagram, based on Wilcox classification Tidar and Bekhon are placed in C2S1 class and Siyahak and Bonab (Sirmand) are placed in C3S1 class. As it is observed this figure, Tidar and Bekhon springs have medium electrical conductivity and low sodium absorption ratio and Siyahak and Bonab (Sirmand) springs have high electrical conductivity and low sodium absorption ratio. Thus, Tidar and Bekhon springs have good quality and Siyahak and Bonab (Sirmand) springs have middle quality.

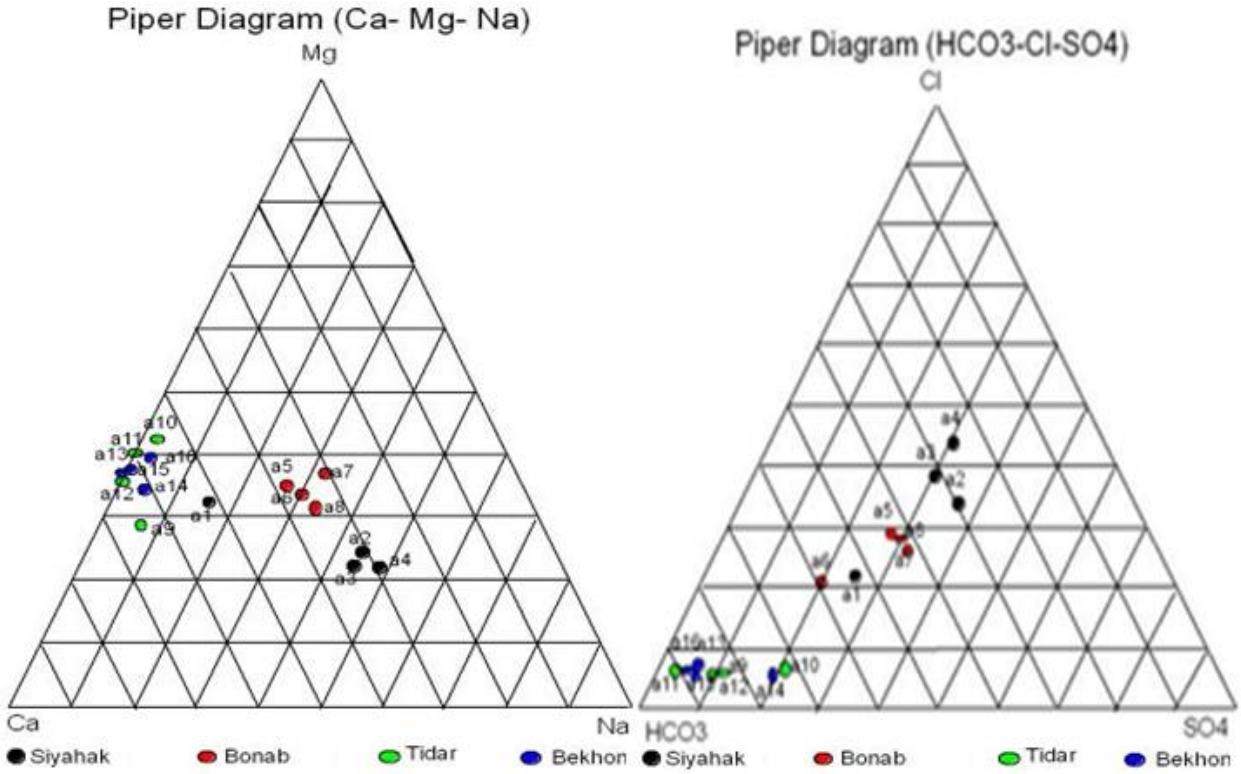

Figure 5: Springs water quality analyzing using of Piper diagram in the study area

Piper Diagram

Considering to figure 5, Tidar and Bekhon springs have more tendency to Ca, Mg, but Siyahak and Sirmand have more tendency to Na and Cl. In fact, Tidar and Bekhon springs have high total hardness in the study area (section A), beside Tidar and Bekhon springs have more tendency to HCO_3 (section B). All of this functions are due to processes that in flow length effect on springs hydrochemistry, thus Tidar and Bekhon springs can be as karstic springs.

Scholler's Diagram

Figure 6 shows that based on Scholler's diagram, drinking water are good quality (due to lower than Sodium and Chloride amount) in Bokhon and Tidar springs, whereas Siyahak and sirmand (Bonab) placed in acceptance quality (due to higher than Sodium and Chloride amount).

To sum up, among the springs, it can be concluded that Tidar and Bekhon springs have good quality and Sirmand (Bonab) and Siyahoo have acceptable quality. On the other hand, it can be concluded that Pabde and Sarvak formation have good permeability in the study area. In fact, Pabde and Sarvak formation play the important role in groundwater resources development.

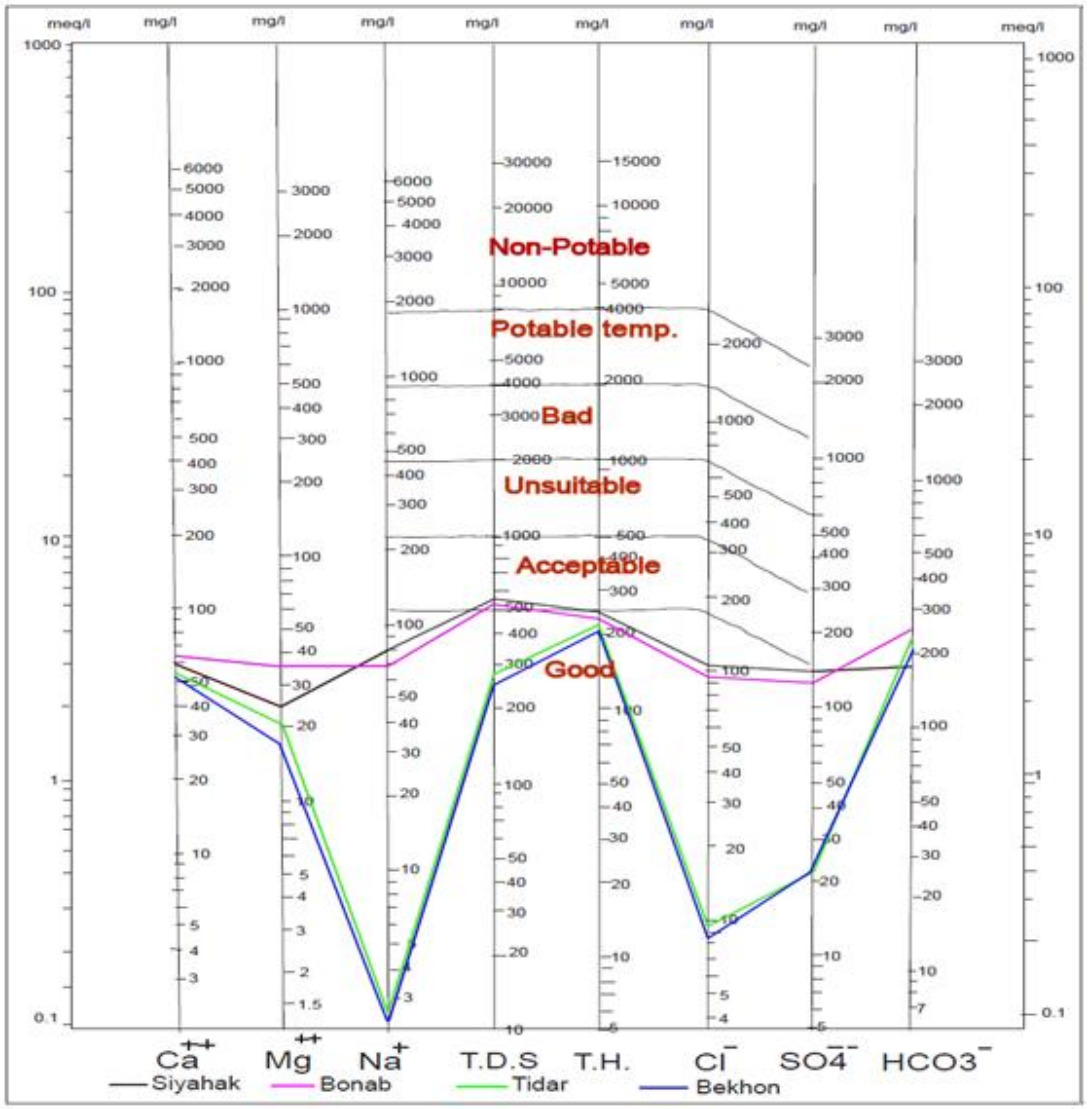

Figure 6: Scholler's diagram in the study area

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